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(71) Applicant:
Akebono Brake Industry Co., Ltd.
Tokyo 103-0016 (JP)

(72) Inventors:
- ESASHI, Masayoshi
Sendai-shi, Miyagi 982-0807 (JP)
- MATSUNAGA, Tadao,
Akebono Brake Industry Co., Ltd.
Tokyo 103-0016 (JP)
- KUNIMI, Takashi,
Akebono Brake Industry Co., Ltd.
Tokyo 103-0016 (JP)
- NEZU, Masahiro,
Akebono Brake Industry Co., Ltd.
Tokyo 103-0016 (JP)
- MORI, Masatomo,
Akebono Brake Industry Co., Ltd.
Tokyo 103-0016 (JP)

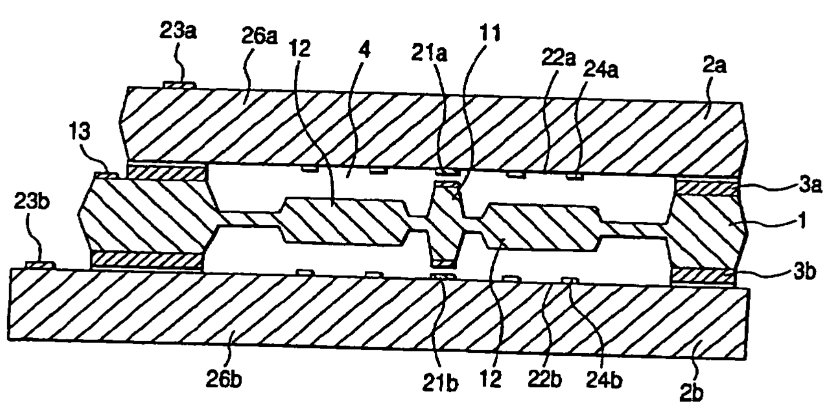
(74) Representative:
Grünecker, Kinkeldey,
Stockmair & Schwanhäusser
Anwaltssozietät
Maximilianstrasse 58
80538 München (DE)

(54) SEMICONDUCTOR ACCELERATION SENSOR AND SELF-DIAGNOSIS THEREOF

(57) The invention provides a semiconductor acceleration sensor which is small in size, light in weight, simple in manufacture, low in manufacturing cost, and high in accuracy, and which, with a switch-on time set to a predetermined value, is stable in operation.

In a semiconductor acceleration sensor in which a central board 1 having a central contact section 11, and outside boards 2 at least one of which has an outside contact section 21 are stacked; the central board 1 has a weight 12 near the central contact section 11, and the outside board 2 having the outside contact section 21 has a weight confronting section 11 which confronts with the weight 12, for squeezed damping effect.

FIG. 1



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Description

Technical Field

[0001] The present invention relates to a semiconductor speed sensor, and its self-diagnosing method, and more particularly to a semiconductor acceleration sensor, and its self-diagnosing method which utilizes a squeezed film effect.

Background Art

[0002] An example of a conventional acceleration sensor employs a ball (like an iron ball). In the sensor, when an acceleration greater than a predetermined value is applied to the sensor, the ball is moved to operate a switch. In another example of the conventional acceleration sensor, a mercury switch is employed (cf. Japanese Utility Patent Application (OPI) No. 136565/1992 and 127574 (the term "OPI" as used herein means an "unexamined published application"). Those conventional sensors are bulky, and are made up of a number of components, and therefore it is necessary to determined a particular position to install them, and they are high in manufacturing cost.

[0003] An object of the invention is to provide a semiconductor acceleration sensor which is small in size, light in weight, simple in manufacture, low in manufacturing cost, and high in accuracy, and which, with a switch-on time set to a predetermined value, is stable in operation.

Description of the Invention

[0004] What is provided by the invention is a semiconductor acceleration sensor in which a central board having a central contact section, and outside boards at least one of which has an outside contact section are stacked; in which the central board has a weight near the central contact section, and the outside board having the outside contact section has a weight confronting section which confronts with the weight.

[0005] In the semiconductor acceleration sensor of the invention, the weight provides a squeezed damping effect in cooperation with the weight confronting section.

[0006] In the semiconductor acceleration sensor, the weight has a central electrode section, and the weight confronting section has an outside electrode section.

[0007] Furthermore, what is provided by the invention is a semiconductor acceleration sensor self-diagnosing method which diagnoses the above-described semiconductor acceleration sensor. In the method, voltage is applied across the central electrode section and the outside electrode section to perform self-diagnosis.

[0008] In addition, what is provided is a semiconductor acceleration sensor in which a central board having a central contact section, and outside boards at least one of which has an outside contact section are stacked. In the sensor, the central contact section and the outside contact section are welded together when they are brought into contact with each other.

Brief Description of the Drawings

[0009]

FIG. 1 is an explanatory diagram of an example of a semiconductor acceleration sensor, which constitutes a first embodiment of the invention.

FIG. 2 is an explanatory diagram for a description of the semiconductor acceleration sensor shown in FIG. 1.

FIG. 3 is an explanatory diagram for a description of the semiconductor acceleration sensor shown in FIG. 1.

FIG. 4 is an explanatory diagram for a description of a both-direction operation of the semiconductor acceleration sensor shown in FIG. 1.

FIG. 5 is an explanatory diagram for a description of the manufacturing steps of the central board of the semiconductor acceleration sensor shown in FIG. 1.

FIG. 6 is an explanatory diagram for a description of the manufacturing steps of the central board (or the first layer) of the semiconductor acceleration sensor shown in FIG. 1.

FIG. 7 is an explanatory diagram for a description of the manufacturing steps of the outside board (or the third layer) of the semiconductor acceleration sensor shown in FIG. 1.

FIG. 8 is an explanatory diagram for a description of the assembling steps of the semiconductor acceleration sensor shown in FIG. 1.

FIG. 9 is an explanatory diagram for a description of another example of the semiconductor acceleration sensor, which constitutes a second embodiment of the invention.

FIG. 10 is an explanatory diagram for a description of the operation of another example of the semiconductor acceleration sensor, which constitutes a third embodiment of the invention.

Best Mode for Carrying Out the Invention

[0010] The invention will be described with reference to its preferred embodiments.

[0011] The semiconductor acceleration sensor and its self-diagnosing method of the invention will be described with reference to the embodiments. FIG. 1 is an explanatory diagram of an example of a semiconductor acceleration sensor, which constitutes a first embodiment of the invention. FIG. 2 is an explanatory diagram for a description of the semiconductor acceleration sensor shown in FIG. 1. FIG. 3 is an explanatory diagram for a description of the semiconductor acceleration sen-

sor shown in FIG. 1. FIG. 4 is an explanatory diagram for a description of a both-direction operation of the semiconductor acceleration sensor shown in FIG. 1. FIG. 5 is an explanatory diagram for a description of the manufacturing steps of the central board of the semiconductor acceleration sensor shown in FIG. 1. FIG. 6 is an explanatory diagram for a description of the manufacturing steps of the central board (or the first layer) of the semiconductor acceleration sensor shown in FIG. 1. FIG. 7 is an explanatory diagram for a description of the manufacturing steps of the outside board (or the third layer) of the semiconductor acceleration sensor shown in FIG. 1. FIG. 8 is an explanatory diagram for a description of the assembling steps of the semiconductor acceleration sensor shown in FIG. 1. FIG. 9 is an explanatory diagram for a description of another example of the semiconductor acceleration sensor, which constitutes a second embodiment of the invention, and FIG. 10 is an explanatory diagram for a description of the operation of another example of the semiconductor acceleration sensor, which constitutes a third embodiment of the invention.

[0012] The first embodiment will be described with reference to FIGS. 1 through 8. The semiconductor acceleration sensor, the first embodiment, is to detect whether or not an acceleration in the direction of lamination of a layered product is larger than a predetermined value, and, as shown in FIG. 2, comprises a central board 1, outside boards 2a and 2b, and sealing insulation sections 3a and 3n, which form the layered product. The central board 1 is, for instance, made of Si, and includes a central contact section 11, a weight 12, and a central terminal section 13. The outside boards 2a and 2b are, for instance, made of Si, and includes outside contact sections 21a and 21b, weight confronting sections 22a and 22b, and outside terminal sections 23a and 23b. Since the central board 1 and the outside board 2 is made of a conductive material, Si, and therefore the central contact section 11 and the outside contact section 21 are connected to the central terminal section 13 and the outside terminal section 23, respectively. Grooves or holes are formed in the central board 1 by etching or the like so that the central contact section 11 is larger in height than the weight 12, and central contact section 11 is small in area than the weight 12. The weight 12 is, for instance, O-shaped, and is provided near the central contact section 11. The outside contact section 21 and the weight confronting section 22 are confronted with the central contact section 11 and the weight 12, and the weight confronting section 11 has a stopper 24. In FIG. 1, the outside contact sections 21a and 21b are provided on the outside boards 2a and 2b, and are vertically symmetrical with each other; however, outside contact section may be provided on only one of the outside boards. The central board 1 and the outside boards 2a and 2b are spaced a predetermined distance by means of the sealing insulation sections 3a and 3b, and are sealed to form a sensor space 4. The sensor space 4 is filled with a gas such as nitrogen gas and inert gas under a predetermined pressure. The central contact section 11 and the outside contact section 21 are led out of the semiconductor acceleration sensor, respectively, through the central wiring section formed in the weight 12 and the outside wiring section 26 formed in the weight confronting section 22, and through the central terminal section 13 and the outside terminal section 23, and are connected to an external circuit device (not shown).

[0013] An acceleration detecting method with the semiconductor acceleration sensor according to the embodiment will be described. When an acceleration is applied to the semiconductor acceleration sensor, the central contact section 11 and the weight 12 are moved thereby. When the acceleration is greater than a predetermined value, the central contact section 11 and the weight 12 are brought into contact with the outside contact section 21 (cf. FIG. 2), so that the fact that the central wiring section and the outside wiring section 26 are conducted to each other can be detected with the external circuit device. That is, it can be determined that the acceleration greater than the predetermined value is applied to the semiconductor acceleration sensor. When the acceleration becomes smaller than the predetermined value, the central contact section 11 is left from the outside contact section 21. In the embodiment, the weight 12 is provided near the central contact section 11, and therefore the weight is also moved in the direction of lamination by the acceleration; that is, it comes near the weight confronting section 22 of the outside board 2, and, owing to the squeezed damping effect, contacts a stopper 24 with a little phase shift (or operation delay). In this case, the weight 22 is spaced a predetermined distance from the weight confronting section owing to the stopper 24. And, when the acceleration is decreased, the weight 12 and the stopper 14 are not immediately left front each other because of the squeezed damping effect, and therefore, as for the external circuit device, it is possible to increase the time of conduction in the semiconductor acceleration sensor. The squeezed damping effect can be determined by the area of the weight confronting section 22, the height of the stopper 24, and the pressure in the sensor space 4. As for the central contact section 11, it is preferable that it is higher than the weight 12, and grooves or holes are formed therein by etching or the like, or the surface is decreased, thereby to decrease the squeezed damping effect. (That is, the on and off operations are not effected without a certain impulse.)

[0014] Now, the squeezed damping (or squeezed film) effect will be described. A device or system of the order of microns, may be affected by the nature of a fluid in a minute flow path. If the flow path is narrow, then the surface area is large when compared with the volume, and therefore it is necessary to take into consideration the viscous force of the flow path which is due to the wall surface, and the viscosity of the present fluid itself. The

squeezing damping effect is one of them. When the narrow distance between the opposed surfaces is changed, then because of the flow present between those surfaces the force opposite to the force which is in the direction of change is effected, thus resulting in the damping effect. If it is supposed that the damping effect (coefficient) = adhesive strength F, then

$$F = u\,s\,v\,/\,d$$

where u: viscous coefficient
s: area
v: speed
d: distance

[0015] It is well known in the art that when d is very small (of the order of microns), $F = u\,s\,v\,/\,d^3$.

[0016] That is, when the distance d in the gap is small, then the adhesive strength F becomes considerably great. This is called "squeezed film effect". This effect is utilized for the "squeezed damping". This is, the damping is effected with a great force to change the distance in the gap with this effect utilized. This fact is called "squeezed damping".

[0017] The operation of the semiconductor acceleration sensor according to the first embodiment will be described with reference to FIG. 3 in detail.

(1) In the case where the acceleration is zero (0) - - t_0 (FIG. 3(a))

When the acceleration is zero (0), no force is applied to the semiconductor acceleration sensor, and accordingly the central contact section 11 and the weight 12 are not moved.

(2) when the acceleration is applied to the sensor, and the switch is turned on or off -- t_1 (FIG. 3(b)).

When an acceleration is applied to the semiconductor acceleration sensor, a force is applied to the sensor. When the forcer is greater than a predetermined value, the central contact section 11 is brought into contact with the outside contact section 21. Hence, the external circuit detected that the semiconductor acceleration sensor has been operated. In this operation, since the weight 12 is smaller in height than the central contact section 11, weight 12 is not brought into contact with the stopper 24. With respect to the squeezed film effect acting on the central contact section 11 is small in area, and therefore the squeezed film effect acting on the central contact section 11 scarcely delays. In this case, the delay due to the damping is only mechanical ones.

(3) When the acceleration is further increased -- t_1 to t_2 FIG. 3(c)).

In this case, the weight 12 is brought into contact with the stopper 24, too. Because of the presence of the stopper 24, the weight 12 and the weight confronting section 22 is spaced a predetermined distance.

(4) When the acceleration is decreased -- t_2 to t_3 (FIG. 3(c))

In this case, owing to the squeezed film effect of the fluid which is present in the gap, the central contact section 11 and the weight 12 are kept contacted therewith. Therefore, the time instant the switch (sw) is turned off delays, and the switch "on" time (t_3 - t_1) is longer than the operation time (t_2 - t_1) of the acceleration which is larger than a predetermined value.

(5) When the acceleration is further decreased -- t_3 - t_4 (FIG. 3(a))

In this case, the weight 12 and the central contact section 11 are left from the weight confronting section 22 and the outside contact section 21, so that the switch is turned off.

One example of the operation of the semiconductor acceleration sensor, which is vertically symmetrical as shown in FIG. 1, will be described with reference to FIG. 4.

The semiconductor acceleration sensor thus formed is able to detect an accelerator no matter in what lamination direction (the layered product) it faces. In the case where the acceleration as shown in FIG. 4 is applied to the sensor, at the time instants t_1 and t_2 the value of the acceleration is less than the predetermined value, and therefore the switch of the semiconductor acceleration sensor is not turned on. At the time instant t_3, the upper switch is turned on; at the time instant t_4, the switch is turned off; and at the time instant t_5, the lower switch is turned on, and at the time instant t_6, the switch is turned off.

Now, an example of a method of manufacturing the semiconductor acceleration sensor, the first embodiment, will be described with reference to FIGS. 5 through 8.

The manufacturing work will be described in the following order:

The manufacture of 1) the central board 1, 2) the outside board (the first layer) 2a, and 3) the outside board (the second layer) 2b; and 4) the assembling work of the semiconductor acceleration sensor.

1) The manufacturing work of the central board 1 (cf. FIG. 5)

A Si board is prepared (FIG. 5(a)), and it is subjected to etching or the like to form the central contact section 11 and the weight 12 as required in shape (the part (b) of FIG. 5). Terminals Al and Au are formed on the central contact section 11 by vacuum evaporation or sputtering. Thus, the central board 1 has been formed (FIG. 5(c)).

2) The manufacturing work of the outside board (the first layer) 2a (cf. FIG. 6).

A Si board is prepared (FIG. 6(a)), and a SiO_2

or glass layer is formed thereon by sputtering or vacuum evaporation, and the sealing insulation section 3a is formed by photo-lithography (FIG. 6(b)). Next, wiring through-holes 25a are formed by etching or the like, and the stopper 24a is formed with SiO_2 (FIG. 6(c)). The outside terminal section 23a is formed by vacuum-evaporating or sputtering Al and Au. Thus, the outside board (the first layer) 2a has been formed (FIG. 6(d)).

3) The manufacturing work of the outside board (the third layer) 2b (cf. FIG. 7).

A Si board is prepared (FIG. 7(a)), and a SiO_2 or glass layer is formed thereon by sputtering or vacuum evaporation, and the sealing insulation section 3b is formed by photo-lithography. The stopper 24a is formed with SiO_2 (FIG. 7(b)). The outside terminal section 23b is formed by vacuum-evaporating or sputtering Al and Au. Thus, the outside board (the third layer) 2b has been formed (the part (c) of FIG. 7).

4) The assembling work of the semiconductor accelerator sensor (cf. FIG. 8)

The outside board (the third layer) 2b, the central board 1, and the outside board (the first layer) 2a are stacked one on another in the stated order (FIG. 8(a)), and they are joined together with the sealing insulation sections 3a and 3b by anode joining (FIG. 8(b)). The unit thus obtained is subjected to dicing, and wires from the terminal sections 13, 23a, and 23b are wire-bonded. The unit thus treated is packaged, to assemble the semiconductor accelerator sensor (FIG. 8(c)).

[0018] Now, another example of the semiconductor accelerator sensor, which constitutes a second embodiment of the invention, will be described.

[0019] As shown in FIG. 9, the sensor includes a central board 1 and outside boards 2a and 2b. Comparing with the first embodiment, in the second embodiment the weight 12 is a central electrode section, and the outside boards 2a and 2b are different from those of the first embodiment. In the second embodiment, the outside boards 2a and 2b are made of insulating material such as glass. And as wiring means to outside terminal sections 23a and 23b, outside wiring sections 26a and 26b are formed in holes 25a and 25b with conductive epoxy, which are formed in the board 2. In the semiconductor acceleration sensor according to the second embodiment, metal (Al, Au and Cr) is vacuum-evaporated or sputtered to form self-diagnosing electrode sections 27a and 27b, and self-diagnosing wiring section 28a and 28b. The self-diagnosing electrode sections 27a and 27b, and self-diagnosing wiring sections 28a and 28b are not connected to the outside wiring sections 26a and 26b.

[0020] The self-diagnosing method will be described with reference to the central board 1 and the outside board 2a. When voltage is applied across the central electrode section of the weight 12 and the outside electrode section 27a, the weight 12 is displaced being attracted towards the outside electrode section 27a, so that the electrostatic capacitance is changed. The relation between the applied voltage and the electrostatic capacitance change is utilized for the self-diagnosis of the semiconductor acceleration sensor. More specifically, it can be self-diagnosed whether or not, for instance, the weight 12 is shaped correctly by performing the self-diagnosis at the time of manufacture of the semiconductor acceleration sensor. The outside board 2a is of insulation material, and therefore it will not affect the electrostatic capacitance at the time of self-diagnosis. When, during the manufacture or use, a higher voltage is applied across the central electrode section of the weight 12 and the outside electrode section 27a, the weight 12 is displaced being attracted by the outside electrode section 27a, so that the centra contact section 11 is brought into contact with the outside contact section 21a; that is, the switch is turned on. Thus, the operations of the semiconductor acceleration sensor and of the external circuit device can be self-diagnosed. The outside electrode section 27a may be utilized as the stopper 24a of the semiconductor acceleration sensor, the first embodiment.

[0021] Another example of the semiconductor acceleration sensor, which constitutes a third embodiment of the invention, will be described with reference to FIG. 10. The semiconductor acceleration sensor, the third embodiment, includes: a central board 1, and outside boards 2a and 2b, which form a layered product; and sealing insulation sections 3a and 3b. In the third embodiment, in order that the contacts may be fused by the operating current, the central contact section 11 and the outside contact section 21a are small in electric capacity. This can be achieved by decreasing the areas of the contacts. When the acceleration is increased, so that the central contact section 11 is brought into contact with the outside contact section 21a, the switch is turned on; however, in this case, the contacts are welded together, so that the chattering is eliminated; that is, the semiconductor acceleration sensor is stable in operation. For instance, in the case where it is used as an air bag switch, all that is necessary for it is its operation which is carried out only once. Hence, it may be employed as an air bag switch. During the self-diagnosis, it is preferable that the inspection is carried out with small current; in this case, no problem is involved therewith. In the third embodiment, it is unnecessary that the contacts are large in electric capacity, and therefore the resultant semiconductor acceleration sensor is low in manufacturing cost as much.

Industrial Applicability

[0022] According to the invention, a semiconductor acceleration sensor can be provided which is small in size, light in weight, simple in manufacture, low in man-

ufacturing cost, and high in accuracy, and which, with a switch-on time set to a predetermined value, is stable in operation.

Claims

1. A semiconductor acceleration sensor in which a central board having a central contact section, and outside boards at least one of which has an outside contact section are stacked,
CHARACTERIZED in that

    said central board has a weight near said central contact section, and
    said outside board having said outside contact section has a weight confronting section which confronts with said weight.

2. A semiconductor acceleration sensor as claimed in claim 1,
CHARACTERIZED in that

    said weight provides a squeezed damping effect in cooperation with said weight confronting section.

3. A semiconductor acceleration sensor as claimed in claim 1 or 2,
CHARACTERIZED in that

    said weight has a central electrode section, and
    said weight confronting section has an outside electrode section.

4. A semiconductor acceleration sensor self-diagnosing method which diagnoses said semiconductor acceleration sensor as claimed in claim 3,
CHARACTERIZED in that

    voltage is applied across said central electrode section and said outside electrode section to perform self-diagnosis.

5. A semiconductor acceleration sensor in which a central board having a central contact section, and outside boards at least one of which has an outside contact section are stacked,
CHARACTERIZED in that

    said central contact section and said outside contact section are welded together when said central contact section and said outside contact section brought into contact with each other.

FIG. 1

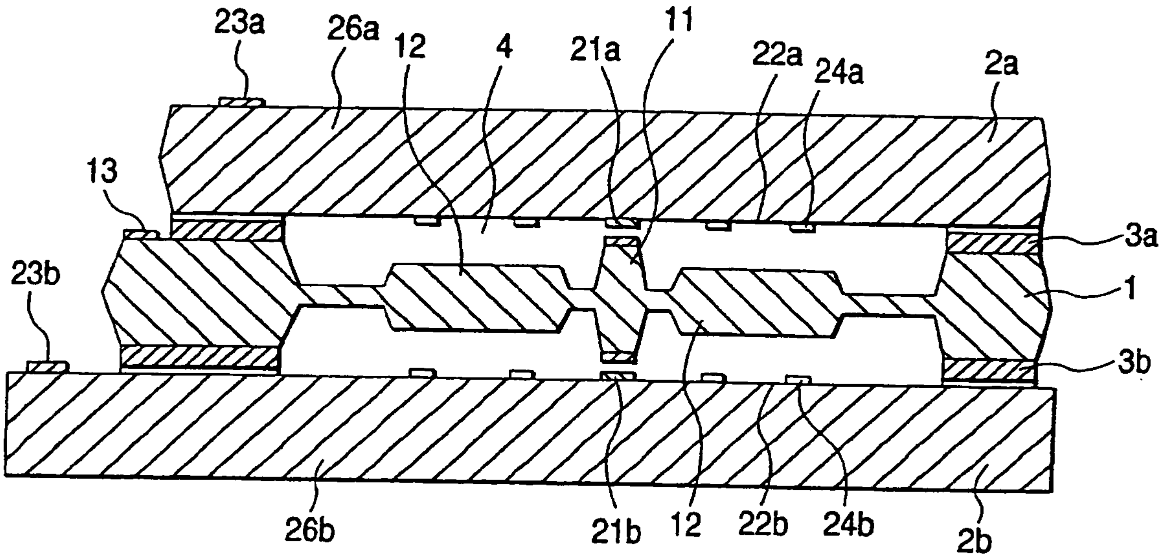

23a
26a
12
4
21a
11
22a
24a
2a
13
3a
23b
1
3b
26b
21b
12
22b
24b
2b

FIG. 2

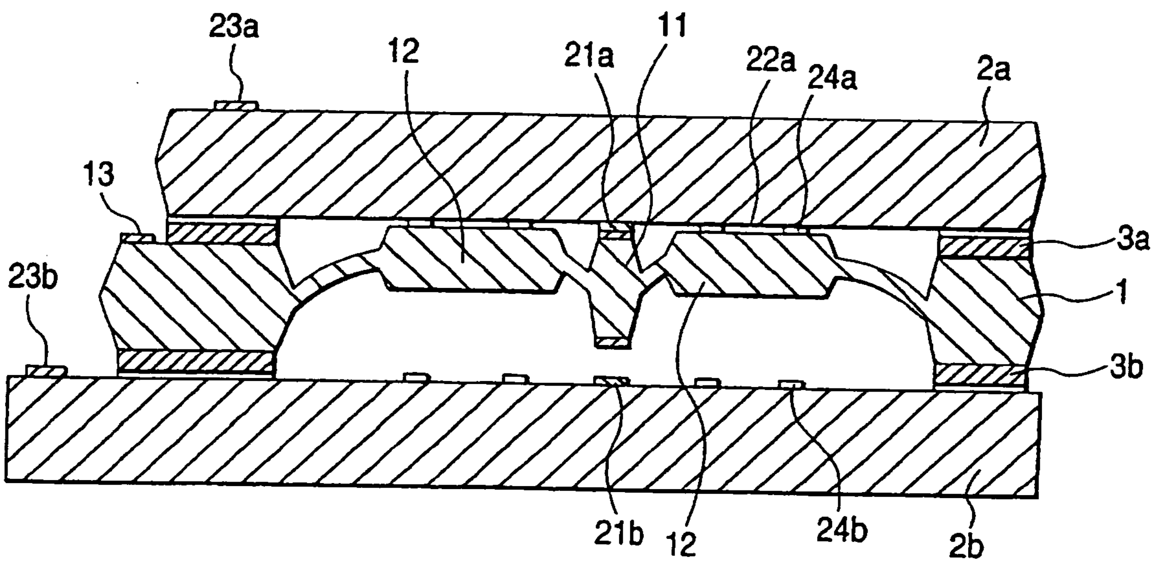

23a
12
21a
11
22a
24a
2a
13
3a
23b
1
3b
21b
12
24b
2b

FIG. 3 (a)

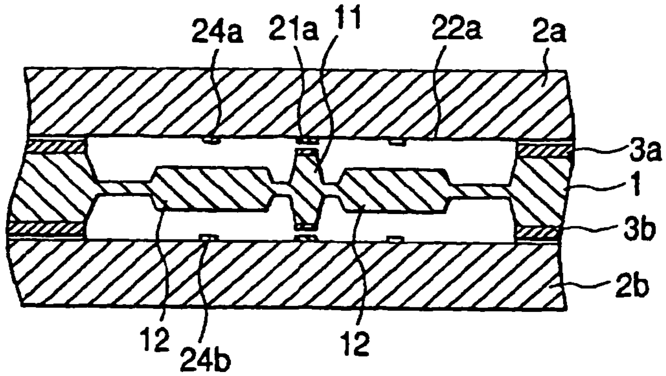


FIG. 3 (b)

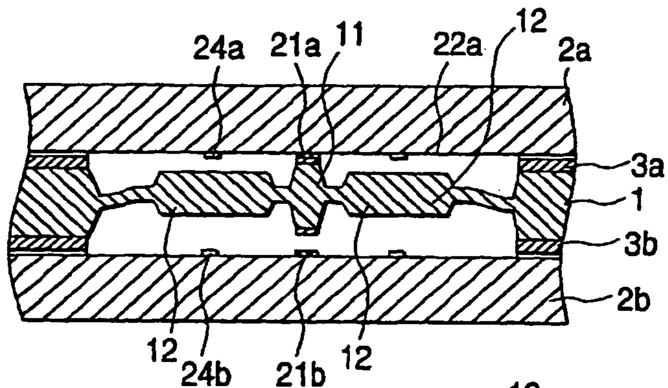


FIG. 3 (c)

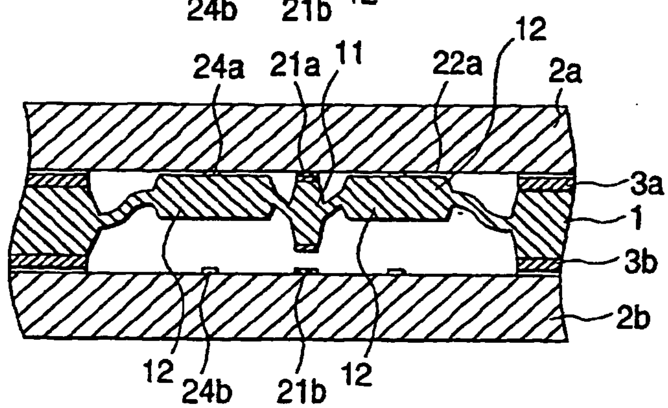


FIG. 3 (d)

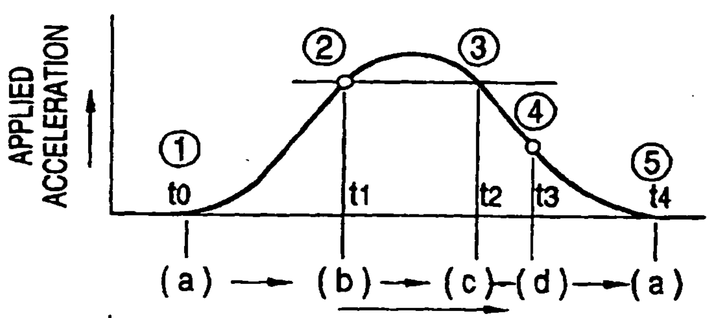


FIG. 3 (e)

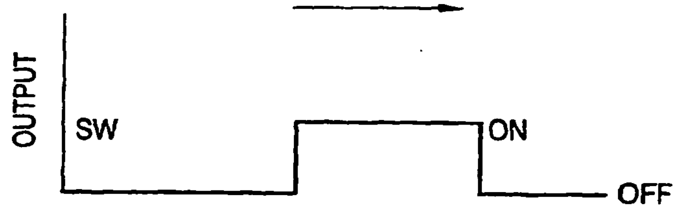


FIG. 4

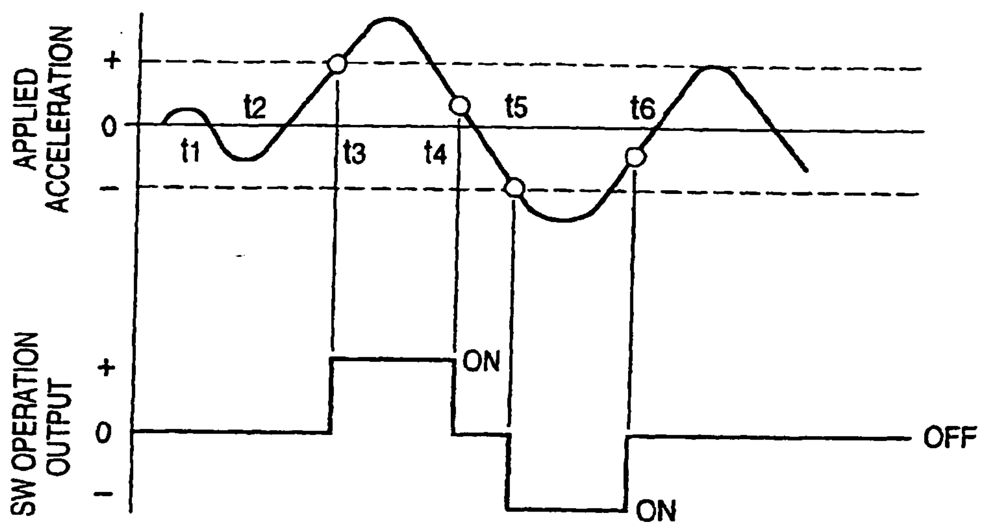


FIG. 5(a)

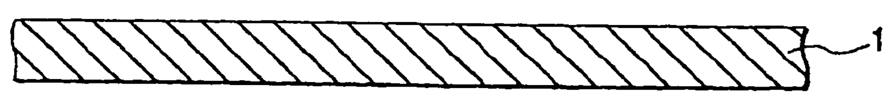


FIG. 5(b)

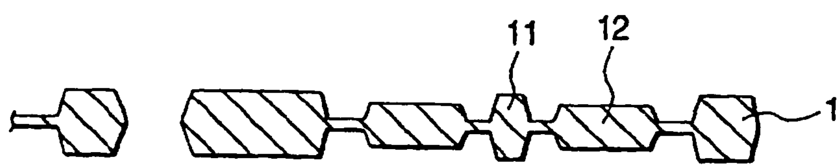


FIG. 5(c)

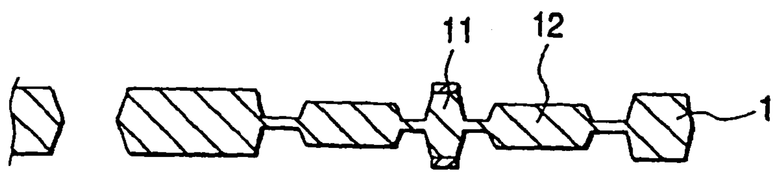


FIG. 6 (a)

FIG. 6 (b)

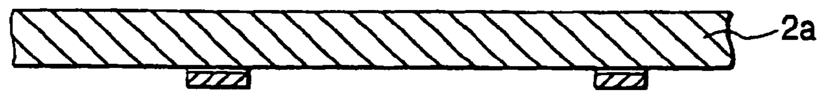


FIG. 6 (c)

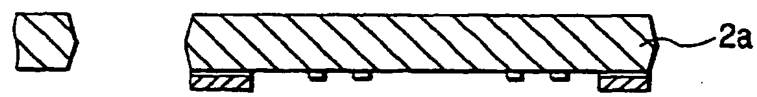


FIG. 6 (d)

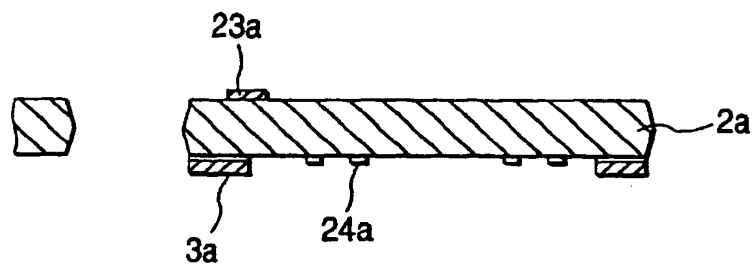


FIG. 7 (a)

FIG. 7 (b)

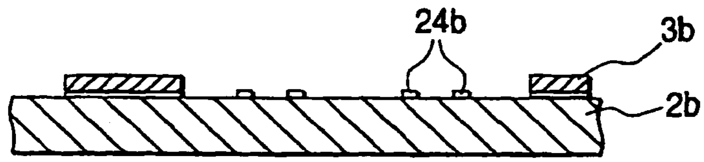


FIG. 7 (c)

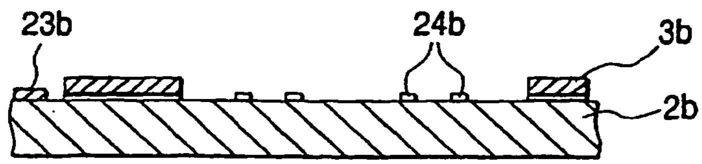


FIG. 8 (a)

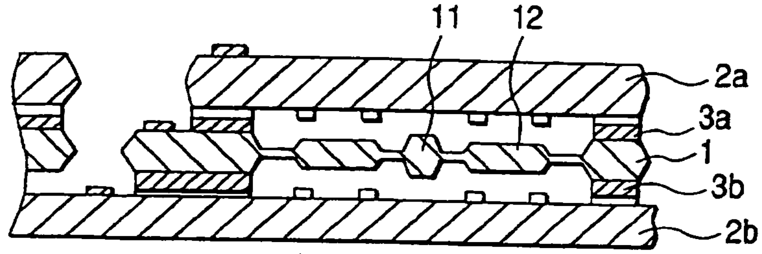


FIG. 8 (b)

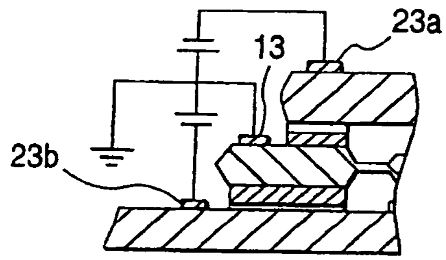


FIG. 8 (c)

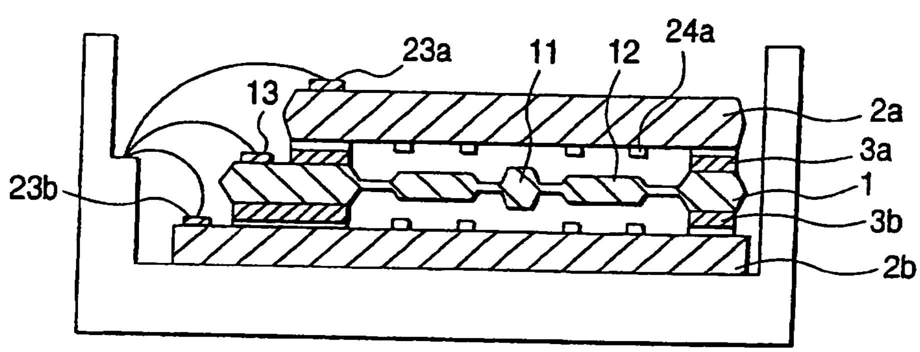


FIG. 9

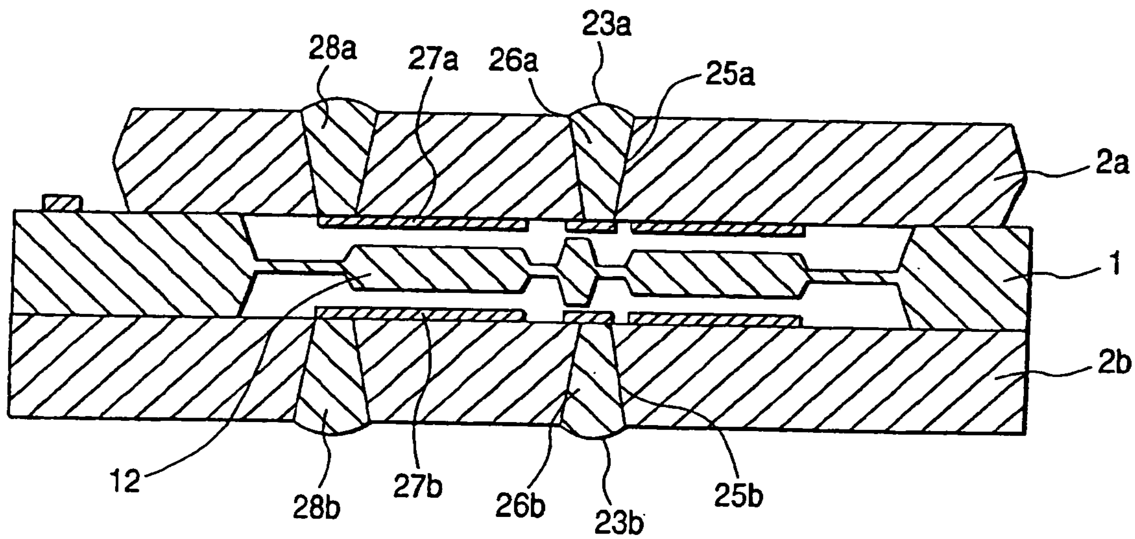
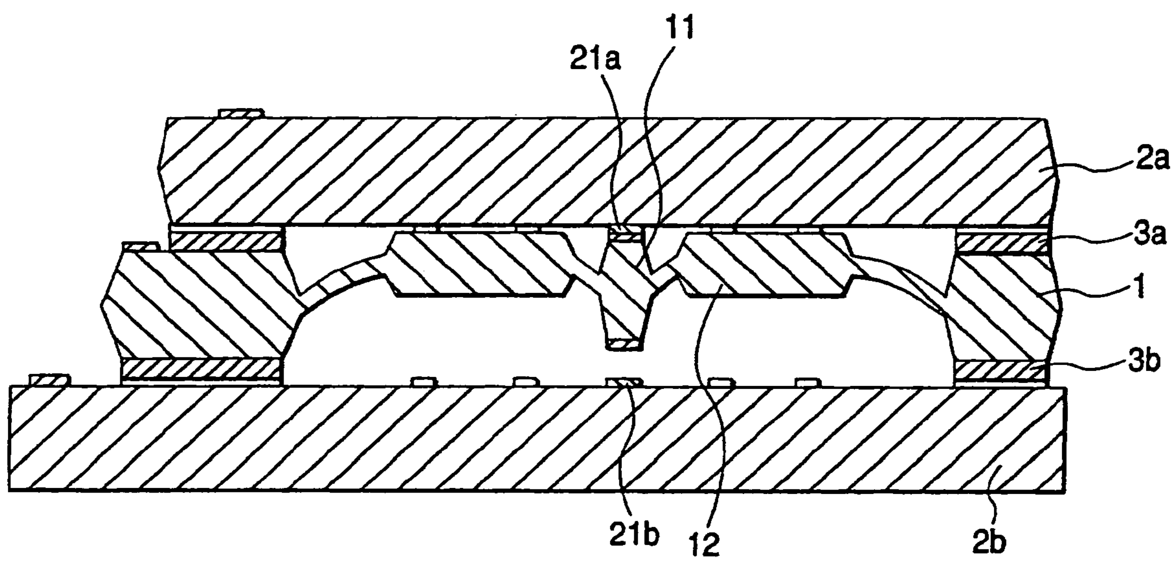


FIG. 10



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP99/00725

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl[6] G01P15/135, H01H35/14

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int.Cl[6] G01P15/135, H01H35/14, H01L29/84

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Toroku Jitsuyo Shinan Koho	1994-1999
Kokai Jitsuyo Shinan Koho	1971-1999	Jitsuyo Shinan Toroku Koho	1996-1999

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	JP, 9-269336, A (Hitachi,Ltd.), 14 October, 1997 (14. 10. 97),	
X	Par. No. [0018] ; Fig. 13	1-2
Y	Par. No. [0018] ; Fig. 13	3-4
A	Par. No. [0020] ; Fig. 15 (Family: none)	5
Y	JP, 5-188084, A (Delco Electronics Corp.), 27 July, 1993 (27. 07. 93), Par. No. [0017] ; Fig. 1 & EP, 0526923, A1	3-4
A	JP, 61-501233, A (Transensory Devices Inc.), 19 June, 1986 (19. 06. 86), Full text ; Figs. 1 to 8 & WO, 85/03383, A1 & US, 4543457, A & EP, 168493, A1	1
P, Y	JP, 10-68742, A (Akebono Brake Industry Co., Ltd.), 10 March, 1998 (10. 03. 98), Par. Nos. [0027] to [0030] ; Figs. 9 to 12 (Family: none)	3-4

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
8 March, 1999 (08. 03. 99)	16 March, 1999 (16. 03. 99)
Name and mailing address of the ISA/ Japanese Patent Office	Authorized officer
Facsimile No.	Telephone No.

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